A CHECKING TABLE FOR THE METHOD OF CONSTANT STIMULI[1]

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In the computation of a limen, according to the *phi-gamma* hypothesis, from data obtained by the method of constant stimuli (or the method of constant stimulus differences), one finds for every stimulus (or stimulus difference) employed the five values: P, γ P, xP, xxP, and x γ P.[2] It is then necessary to obtain the sum of each one of these five values for all of the stimuli used, namely: [P], [γP], [xP], [xxP] and [xγP]. It is frequently desirable to check the required additions, which, since both positive and negative quantities occur, are especially liable to error. The simplest procedure for checking,[3] known as 'cross-addition,' consists in finding for every stimulus the total of the five values (a total which we shall designate by the symbol 'T'). If no mistakes have occurred in the additions, the sum of the T-values thus obtained will equal the total of the five sums [P], [γP], [xP], [xxP], and [x P].

But the five values mentioned, which are obtained for every stimulus, depend solely on the x and the p (percentage of judgments) for that particular stimulus. If Urban's tables[4] are used we are limited to 15 possible x's (—7 to 7) and 99 possible p's (.01 to .99). There are, then, only 1,485 possible combinations[5] of p and x, and only that number of possible values of the quantity T under these conditions.

The accompanying checking table[6] contains the values of T just mentioned for every x and every p. Every value of T in the table is the sum of the five values P, γ P, xP, xxP, and x γ P for the corresponding x and p, as given in Urban's tables. Every line of the table contains

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[1] From the Department of Psychology, Cornell University.

[2] For the general procedure in these computations see: E. B. Titchener, *Experimental Psychology, Quantitative Student's Manual,* 92 ff., and E. G. Boring, Urban's Tables and the Method of Constant Stimuli, *Amer. Jour. Psych.,* 28, 1917, 280 ff.

[3] The method used by Fernberger and by Urban, and described by Boring, *op. cit.,* 288, involves more labor than does mere 'cross addition,' but localizes more closely any possible errors. Its use here, however, would require two tables instead of our one.

[4] F. M. Urban, Hilfstabellen für die Konstanzmethode, *Arch. f. d. ges. Psych.* 24, 1912, 236 ff. and 25, Literaturber, 84; *Die Praxis der Konstanzmethode,* Leipzig, 1912.
Directions for using these tables will be found in Boring, *op. cit.*

[5] Since 15 × 99 = 1,485.

[6] I am indebted to my former associates in the Cornell Laboratory, Miss J. M. Gleason, Dr. E. G. Boring, Dr. W. S. Foster, Mr. T. B. Hoisington, and Mr. H. G Bishop for much valuable assistance in the preparation of this table; and to Miss K. M. Schutt of Ithaca for her careful work in typing the copy reproduced here.

Table (X = −7 to X = 0)

p	X=-7	X=-6	X=-5	X=-4	X=-3	X=-2	X=-1	X=0
.01	5.8579	4.3203	3.0080	1.1595	.5235	.1127		−.0727
.02	9.7281	7.1974	5.0431	1.8631	.8375	.1881		−.0851
.03	12.5809	9.2914	6.4954	2.3841	1.0686	.2469		−.0813
.04	15.3119	11.2923	8.0749	2.8773	1.2868	.3036		−.0723
.05	17.5872	12.9552	9.0269	3.2818	1.4649	.3516		−.0574
.06	19.6082	14.4293	10.0411	3.6368	1.6207	.3954		−.0392
.07	21.4324	15.7575	10.9527	3.9536	1.7592	.4351		−.0189
.08	23.1571	17.0181	11.7820	4.2398	1.8841	.4718		.0031
.09	24.6313	18.1809	12.5423	4.5005	1.9973	.5059		.0263
.10	26.0376	19.2999	13.2371	4.7373	2.0999	.5376		.0505
.11	27.3456	20.0459	13.8811	4.9550	2.1939	.5673		.0755
.12	28.5668	20.9282	14.4803	5.1565	2.2805	.5953		.1007
.13	29.7416	21.7416	15.0316	5.3406	2.6196	.6215		.1265
.14	30.7546	22.5423	15.5423	5.5118	2.6723	.6463		.1526
.15	31.7421	23.2148	16.0270	5.6696	2.4327	.6697		.1789
.16	32.6789	23.8875	16.4801	5.8178	2.5628	.6921		.2055
.17	33.5392	24.5036	16.8942	5.9520	2.6196	.7129		.2314
.18	34.3503	25.0640	17.2831	6.0772	2.6723	.7327		.2584
.19	35.1151	25.6302	17.6483	6.1938	2.7211	.7515		.2850
.20	35.8351	26.1442	17.9912	6.3024	2.7665	.7695		.3116
.21	36.5089	26.6442	18.3097	6.4022	2.8080	.7865		.3316
.22	37.1383	27.0696	18.6060	6.4942	2.8458	.8025		.3643
.23	37.7315	27.4899	18.8841	6.5795	2.8808	.8179		.3906
.24	38.2837	27.8802	19.1413	6.6595	2.9126	.8323		.4166
.25	38.8005	28.2446	19.3807	6.7292	2.9416	.8460		.4425
.26	39.2815	28.5828	19.6020	6.7945	2.8590	.8590		.4682
.27	39.7311	28.8980	19.8075	6.8542	2.9905	.8713		.4938
.28	40.1505	29.1911	19.9976	6.9084	3.0127	.8830		.5191
.29	40.5354	29.4592	20.1706	6.9567	3.0314	.8939		.5441
.30	40.8950	29.7086	20.3307	7.0004	3.0481	.9043		.5690
.31	41.2256	29.9368	20.4762	7.0390	3.0625	.9140		.5935
.32	41.5304	30.1464	20.6088	7.0731	3.0750	.9232		.6179
.33	41.8022	30.3319	20.7251	7.1016	3.0849	.9317		.6418
.34	42.0577	30.5056	20.8330	7.1269	3.0935	.9398		.6657
.35	42.2810	30.6558	20.9250	7.1471	3.1000	.9473		.6892
.36	42.4819	30.7896	21.0057	7.1632	3.1045	.9542		.7123
.37	42.6633	30.9092	21.0766	7.1758	3.1076	.9607		.7353
.38	42.8156	31.0079	21.1333	7.1836	3.1085	.9666		.7578
.39	42.9487	31.0924	21.1919	7.1880	3.1085	.9720		.7800
.40	43.0548	31.1576	21.2141	7.1880	3.1056	.9768		.8018
.41	43.1459	31.2117	21.2402	7.1853	3.1020	.9814		.8835
.42	43.2124	31.2479	21.2541	7.1784	3.0966	.9853		.8447
.43	43.2573	31.2687	21.2576	7.1681	3.0896	.9888		.8666
.44	43.2815	31.2743	21.2507	7.1542	3.0811	.9918		.9060
.45	43.2847	31.2648	21.2335	7.1367	3.0712	.9943		.9060
.46	43.2736	31.2422	21.2070	7.1162	3.0599	.9964		.9257
.47	43.2305	31.2019	21.1694	7.0920	3.0470	.9980		.9449
.48	43.1732	31.1488	21.1225	7.0645	3.0326	.9991		.9636
.49	43.0967	31.0817	21.0662	7.0339	3.0170	.9998		.9821
.50	43.0000	31.0000	21.0000	7.0000	3.0000	1.0000	1.0000	1.0000

Table (X = 1 to X = 7)

p	X=1	X=2	X=3	X=4	X=5	X=6	X=7
.01	−.0327	.2327	.7235	1.4396	2.2810	3.4479	4.8403
.02	.0179	.4973	1.3529	2.5847	4.1927	6.1770	8.5375
.03	.0843	.7430	1.8953	3.5414	5.5559	8.3142	11.4409
.04	.1590	.9978	2.4437	4.4969	7.1574	10.4251	14.2668
.05	.2371	1.2358	2.9376	5.3436	8.4533	12.2668	16.7842
.06	.3170	1.4637	3.4012	6.1295	9.6485	14.0566	19.0566
.07	.3973	1.6836	3.8400	6.8667	10.8667	15.5305	21.1676
.08	.4780	1.8963	4.2582	7.5637	11.8826	17.0052	23.1413
.09	.5585	2.1025	4.6583	8.2259	12.8053	18.3965	24.9995
.10	.6386	2.3015	5.0397	8.8530	14.6359	19.7048	26.7434
.11	.7179	2.4951	5.4068	9.4531	14.4991	20.9491	28.3994
.12	.7967	2.6835	5.7699	10.0289	15.4875	22.1370	29.9770
.13	.8745	2.8655	6.0994	10.5764	15.5305	23.2964	31.4653
.14	.9511	3.0431	6.4274	11.1043	17.0737	24.3361	32.8910
.15	1.0275	3.2015	6.7428	11.6096	17.8158	25.3614	34.2463
.16	1.1031	3.3848	7.0506	12.1007	18.5479	26.3533	35.5559
.17	1.1767	3.5472	7.3434	12.5654	19.2132	27.2864	36.7858
.18	1.2495	3.7059	7.6276	13.0148	19.8673	28.1850	37.9681
.19	1.3215	3.8611	7.9038	13.4494	20.4981	29.0500	39.1049
.20	1.3927	4.0127	8.1718	13.8699	21.1078	29.8820	40.1894
.21	1.4627	4.1600	8.4304	14.2737	21.6901	30.6791	41.2413
.22	1.5311	4.3032	8.6802	14.6624	22.2496	31.4418	42.2393
.23	1.5991	4.4432	8.9251	15.0388	22.1773	32.1773	43.1699
.24	1.6655	4.5792	9.1575	15.4004	23.3079	32.8800	44.1169
.25	1.7310	4.7118	9.3846	15.7494	23.8063	33.5552	44.9965
.26	1.7954	4.8407	9.6039	16.0852	34.2016	34.2016	45.8369
.27	1.8589	4.9675	9.8168	16.4097	24.7451	34.8232	46.6439
.28	1.9212	5.0891	10.0230	16.7228	25.1886	35.4203	47.4177
.29	1.9821	5.2078	10.2213	17.0226	25.6616	35.9880	48.1530
.30	2.0423	5.3239	10.4142	17.3130	26.0203	36.5362	48.8604
.31	2.1010	5.4367	10.6004	17.5921	26.4118	37.0596	49.5354
.32	2.1590	5.5466	10.7807	17.8611	26.7451	37.5612	50.1810
.33	2.2159	5.6523	10.9526	18.1164	27.1435	38.0341	50.7880
.34	2.2712	5.7567	11.1227	18.3665	27.4908	38.4950	51.3789
.35	2.3257	5.8564	11.2819	18.6019	27.8164	38.9254	51.9254
.36	2.3788	5.9537	11.4370	18.8287	28.1260	39.3374	52.4543
.37	2.4313	6.0488	11.5878	19.0482	28.4300	39.7332	52.9579
.38	2.4822	6.1397	11.7304	19.2543	28.7113	40.1015	53.4248
.39	2.5320	6.2282	11.8684	19.4553	29.0111	40.4530	53.8693
.40	2.5804	6.3128	11.9988	19.6386	29.2319	40.7792	54.2809
.41	2.6284	6.3958	12.1261	19.8191	29.4748	41.0933	54.6743
.42	2.6747	6.4754	12.2468	19.9887	29.7013	41.3845	55.0384
.43	2.7198	6.5516	12.3609	20.1479	29.9124	41.6545	55.3741
.44	2.7638	6.6251	12.4698	20.2983	30.1103	41.9059	55.6849
.45	2.8063	6.6952	12.5727	20.4398	30.2935	42.1368	55.9687
.46	2.8478	6.7625	12.6700	20.5703	30.4634	42.3486	56.2310
.47	2.8878	6.8264	12.7610	20.6915	30.6180	42.5403	56.4585
.48	2.9263	6.8872	12.8461	20.8033	30.7587	42.7122	56.6638
.49	2.9640	6.9454	12.9263	20.9069	30.8870	42.8667	56.8459
.50	3.0000	7.0000	13.0000	21.0000	31.0000	43.0000	57.0000

Upper table

X = 7	X = 6	X = 5	X = 4	X = 3	X = 2	X = 1	p
57.1291	43.1145	31.0994	21.0839	13.0679	7.0516	3.0348	.51
57.2314	43.2088	31.1843	21.1581	13.1299	7.1000	3.0683	.52
57.3079	43.2835	31.2552	21.2225	13.1858	7.1450	3.1002	.53
57.3644	43.3402	31.3122	21.2777	13.2358	7.1869	3.1306	.54
57.3815	43.3730	31.3531	21.3218	13.2791	7.2250	3.1595	.55
57.3781	43.3873	31.3801	21.3565	13.3164	7.2599	3.1870	.56
57.3469	43.3829	31.3920	21.3809	13.3473	7.2914	3.2130	.57
57.2880	43.3529	31.3885	21.3947	13.3716	7.3190	3.2371	.58
57.2007	43.3039	31.3696	21.3981	13.3893	7.3432	3.2600	.59
57.0808	43.2298	31.3325	21.3890	13.3992	7.3630	3.2800	.60
56.9409	43.1406	31.2845	21.3723	13.4042	7.3800	3.3000	.61
56.7654	43.0245	31.2167	21.3421	13.4006	7.3925	3.3174	.62
56.5641	42.8886	31.1346	21.3020	13.3910	7.4012	3.3329	.63
56.3245	42.7238	31.0315	21.2477	13.3758	7.4051	3.3464	.64
56.0588	42.5392	30.9138	21.1831	13.3469	7.4052	3.3581	.65
55.7639	42.3320	30.7796	21.1071	13.3143	7.4011	3.3676	.66
55.4258	42.0356	30.6219	21.0150	13.2716	7.3915	3.3749	.67
55.0660	41.8356	30.4516	20.9141	13.2231	7.3784	3.3802	.68
54.6628	41.5460	30.2574	20.7967	13.1642	7.3595	3.3830	.69
54.2252	41.2304	30.0439	20.6660	13.0966	7.3357	3.3835	.70
53.7494	40.8854	29.8090	20.5145	13.0195	7.3066	3.3813	.71
53.2397	40.5145	29.5550	20.3616	12.9340	7.2723	3.3768	.72
52.6843	40.1086	29.2755	20.1849	12.8370	7.2307	3.3689	.73
52.0891	39.6724	28.9736	19.9928	12.7301	7.1853	3.3586	.74
51.4521	39.2040	28.6481	19.7842	12.6124	7.1328	3.3456	.75
50.7675	38.6994	28.2959	19.5570	12.4829	7.0732	3.3283	.76
50.0361	38.1589	27.9173	19.3114	12.3413	7.0068	3.3083	.77
49.2503	37.5764	27.5078	19.0442	12.1858	6.9324	3.2855	.78
48.4163	36.9573	27.0713	18.7581	12.0178	6.8506	3.2563	.79
47.5249	36.2940	26.6020	18.4491	11.8352	6.7603	3.2243	.80
46.5695	35.5816	26.0965	18.1148	11.6360	6.6603	3.1875	.81
45.5563	34.8246	25.5585	17.7574	11.4218	6.5515	3.1467	.82
44.4814	34.0200	24.9850	17.3752	11.1912	6.4330	3.1007	.83
43.3415	33.1657	24.3741	16.9667	10.9434	6.3044	3.0495	.84
42.0955	32.2338	23.7056	16.5178	10.6694	6.1603	2.9907	.85
40.7906	31.2483	22.9985	16.0415	10.3772	6.0055	2.9263	.86
39.3857	30.1896	22.2366	15.5266	10.0596	5.8355	2.8545	.87
37.8906	29.0614	21.4227	14.9749	9.7177	5.6511	2.7751	.88
36.2716	27.8373	20.5379	14.3731	9.3428	5.4471	2.6859	.89
34.5374	26.5246	19.5869	13.7242	8.9367	5.2243	2.5870	.90
32.6731	25.1109	18.5605	13.0219	8.4951	4.9801	2.4769	.91
30.6405	23.5670	17.4370	12.2507	7.9801	4.7085	2.3528	.92
28.4316	21.8865	16.2115	11.4067	7.4720	4.4076	2.2133	.93
26.0124	20.0429	14.8639	10.4757	6.8782	4.0713	2.0554	.94
23.3324	17.9966	13.3645	9.4362	6.2718	3.6911	1.8743	.95
20.3147	15.6877	11.6682	8.2559	5.4509	3.2532	1.6626	.96
16.6923	12.9092	9.6196	6.8236	4.5211	2.7122	1.3971	.97
12.9081	10.0012	7.4707	5.3163	3.5383	2.1363	1.1107	.98
7.8063	6.6433	4.5056	3.2934	2.2065	1.3451	.7089	.99

Lower table

p	X = 0	X = -1	X = -2	X = -3	X = -4	X = -5	X = -6	X = -7
.51	1.0175	.9998	2.9816	6.9631	12.9441	20.9246	30.9047	42.8843
.52	1.0346	.9991	2.9618	6.9227	12.8817	20.8389	30.7942	42.7476
.53	1.0511	.9980	2.9408	6.8796	12.8141	20.7446	30.6711	42.5935
.54	1.0671	.9964	2.9183	6.8332	12.7407	20.6410	30.5334	42.4230
.55	1.0826	.9943	2.8946	6.7835	12.6610	20.5271	30.3818	42.2251
.56	1.0976	.9918	2.8695	6.7308	12.5757	20.4041	30.2161	42.0115
.57	1.1121	.9888	2.8430	6.6749	12.4843	20.2712	30.0357	41.7777
.58	1.1259	.9853	2.8154	6.6160	12.3873	20.1293	29.8419	41.5252
.59	1.1393	.9814	2.7862	6.5537	12.2841	19.9770	29.6327	41.2511
.60	1.1518	.9768	2.7554	6.4876	12.1738	19.8135	29.4070	40.9540
.61	1.1640	.9720	2.7242	6.4202	12.0603	19.6445	29.1728	40.6451
.62	1.1754	.9666	2.6909	6.3486	11.9393	19.4631	28.9201	40.3102
.63	1.1861	.9607	2.6568	6.2742	11.8132	19.2736	28.6554	39.9587
.64	1.1961	.9542	2.6207	6.1956	11.6789	19.0707	28.3708	39.5793
.65	1.2054	.9473	2.5836	6.1145	11.5401	18.8600	28.0744	39.1834
.66	1.2139	.9398	2.5455	6.0307	11.3959	18.6406	27.7650	38.7691
.67	1.2216	.9317	2.5053	5.9422	11.2426	18.4063	27.4335	38.3240
.68	1.2285	.9232	2.4644	5.8519	11.0859	18.1664	27.0932	37.8666
.69	1.2345	.9140	2.4217	5.7572	10.9209	17.9126	26.7324	37.3802
.70	1.2396	.9043	2.3775	5.6592	10.7496	17.6483	26.3556	36.8714
.71	1.2439	.8939	2.3318	5.5712	10.5712	17.3724	25.9614	36.3382
.72	1.2469	.8830	2.2851	5.4530	10.3870	17.0888	25.5525	35.7841
.73	1.2488	.8713	2.2373	5.3440	10.1943	16.7871	25.1226	35.2007
.74	1.2498	.8590	2.1863	5.2315	9.9948	16.4760	24.6752	34.5925
.75	1.2480	.8460	2.1346	5.1154	9.7880	16.1509	24.2098	33.9589
.76	1.2480	.8323	2.0814	4.9949	9.5732	15.8161	23.7236	33.2959
.77	1.2452	.8179	2.0264	4.8705	9.3506	15.4661	23.2175	32.6045
.78	1.2407	.8025	1.9694	4.7414	9.1184	15.1006	22.6878	31.8785
.79	1.2349	.7865	1.9110	4.6084	8.8787	14.7221	22.1383	31.1275
.80	1.2274	.7695	1.8505	4.4706	8.6297	14.3278	21.5648	30.3409
.81	1.2180	.7515	1.7879	4.3276	8.3020	13.9159	20.9646	29.5165
.82	1.2070	.7327	1.7239	4.1802	7.9648	13.4891	20.3416	28.6593
.83	1.1939	.7129	1.6578	4.0282	7.8244	13.0464	19.6940	27.7676
.84	1.1787	.6921	1.5896	3.8714	7.5373	12.5873	19.0215	26.8397
.85	1.1605	.6697	1.5183	3.7062	7.2336	12.1004	18.3066	25.8521
.86	1.1400	.6463	1.4451	3.5368	6.9211	11.5979	17.5675	24.8298
.87	1.1165	.6215	1.3695	3.3604	6.5944	11.0714	16.7914	23.7543
.88	1.0899	.5953	1.2913	3.1781	6.2555	10.5235	15.9822	22.6316
.89	1.0593	.5673	1.2099	2.9870	5.8987	9.9451	15.1257	21.4414
.90	1.0247	.5376	1.1255	2.7887	5.5268	9.3401	14.2284	20.1920
.91	.9855	.5059	1.0381	2.5821	5.1379	8.7055	13.2849	18.8761
.92	.9405	.4718	.9467	2.3650	4.7269	8.0324	12.2814	17.4739
.93	.8891	.4351	.8512	2.1376	4.2941	7.3207	11.2175	15.9844
.94	.8300	.3954	.7515	1.8982	3.8359	6.5641	10.0831	14.3928
.95	.7612	.3519	.6465	1.6448	3.3470	5.7528	8.8626	12.6762
.96	.6795	.3036	.5350	1.3737	2.8195	4.8728	7.5333	10.8011
.97	.5751	.2469	.4122	1.0711	2.2236	3.8696	6.0092	8.6423
.98	.4613	.1881	.2913	.7705	1.6261	2.8579	4.4660	6.4503
.99	.2981	.1127	.1527	.4181	.9088	1.5250	2.4665	3.6335

the T's for every x used by Urban and a single p, while every column contains the T's for every p and a single x.[7]

The use of the checking table is simple. After obtaining from Urban's tables the five values required for a given stimulus (or stimulus difference), the T for that stimulus, as determined by its x and p, is read from our table and placed in a sixth column. (Note that T is not the same for p and 1.00—p.) The same procedure is followed for every stimulus involved in the calculation. The sum of this sixth column is found just as the sums of the five other columns. If there are no mistakes in computation, the sum of the T-column will be equal to the sum of the sums of the other five columns. For, since each T is obtained according to the formula,

$$T = P + \gamma P + xP + xxP + x\gamma P,$$

it follows that

$$[T] = [P] + [\gamma P] + [xP] + [xxP] + [x\gamma P].$$

If, however, the sum of the T-column is not equal to the sum of the other five columns, a mistake has been made. There are two possible sources of error. One possibility is that one or more of the additions is wrong; the other is that an error has been made in copying from either Urban's tables or the checking table. In practice, the writer has found most of his discrepancies to be due to the latter cause.

In building the checking table, we used Urban's tables as published in *Die Praxis der Konstanzmethode,* 1912, which contains two corrections of the tables as originally published in the *Archiv* (for 6^2P when $p = .89$ and .90). In the course of our work, another error in Urban's tables (both editions) came to light. The value 5^2P when $p = .90$ is given as 14.4388 and should be 13.4388. We used the corrected value, and our table will show this discrepancy from either edition of Urban.

[7] The values of T were themselves checked by finding the sum of each column in our table. It can readily be shown that the sums of two columns of T, having x's numerically equal but different in sign, differ by 2 $[xP]$. The columns in our table were required to show this difference as a criterion of correctness.